



Agenda

- Statement of challenges
- Capabilities to meet challenges
- Experiments run with real satellites to validate new capabilities
 - EO-1
 - CHIPS
 - ST-5
- Conclusion

Challenges for Future Missions

- Manage increased mission complexity at lower cost
- Create flexible missions with interoperable components
- Increase mission safety by embedding intelligence to manage security and hazard avoidance

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Key Capabilities To Meet Challenges

- Transition from centralized mission control to distributed control
- Maximize interoperability by abstracting as much mission functionality as possible
- Develop and use self-managing software components (autonomic computing)
 - (1) Components have self-awareness
 - (2) Self-optimization
 - (3) Self-healing
 - (4) Self-protection
 - (5) Negotiates (peer-to-peer) for resources
 - (6) Functions in a heterogeneous world and with open standards
 - (7) Anticipates needed resources and hides details needed to obtain resources

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Series of Experiments Conducted

- Used following missions to conduct experiments to facilitate these capabilities:
 - Earth Observing 1 (EO-1)
 - Cosmic Hot Interstellar Plasma Spectrometer (CHIPS)
 - Space Technology 5 (ST-5)
- Experiment with Service Oriented Architectures (SOA)

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EO-1 Satellite

Launched November 21, 2000

NASA New Millennium Program space technology validation mission

Hyperion – hyperspectral instrument

Advance Land Imager (ALI) – multispectral instrument

10 other space technologies validated

■ 2 Mongoose onboard computers with 256 Mbytes each

■ Presently in extended mission and being used for additional experiments with hyperspectral imagery and sensor web experiments

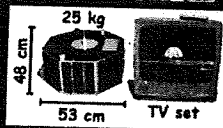
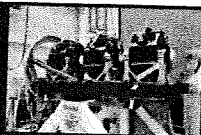
Cosmic Hot Interstellar Plasma Spectrometer (CHIPS): A Flying Networked Computer Testbed for Advanced Mission Concepts

- PowerPC
- Onboard IP Stack
- 128 Mbytes of Memory
- Perfect for Experiments
-(E.g. Secure IP to S/C)

**** OPEN FOR BUSINESS 9/1/05 ****

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ST-5 Overview



Not much bigger than a large birthday cake or a small TV.

ST-5 is a three satellite (micro-sat) constellation

NASA New Millennium Program technology validation mission

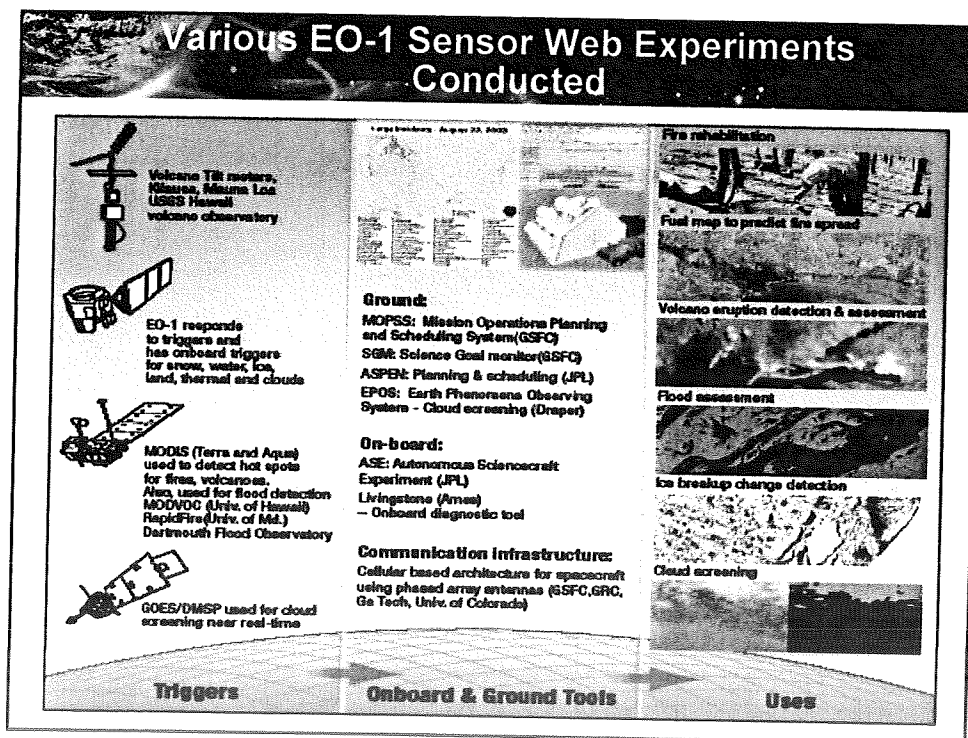
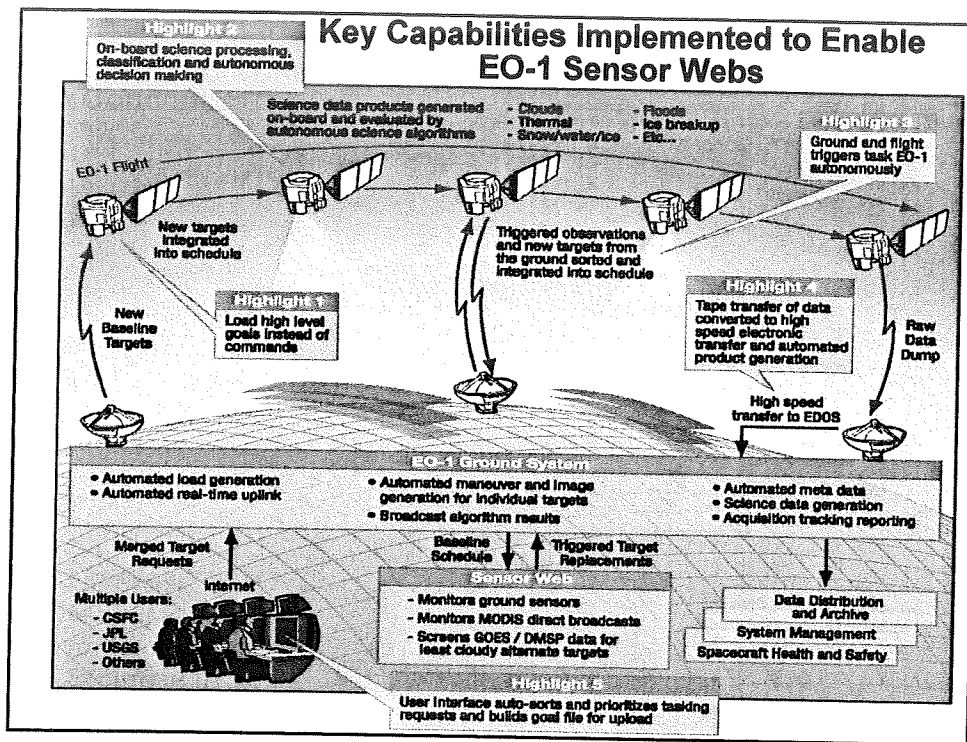
Help scientists understand the Earth's magnetosphere and its effect on space weather

Uses the GMSEC architecture to enable cost-effective model-based operations to run the ST-5 constellations lights-out

Launched March 22, 2006

Successfully completed mission June 22, 2006

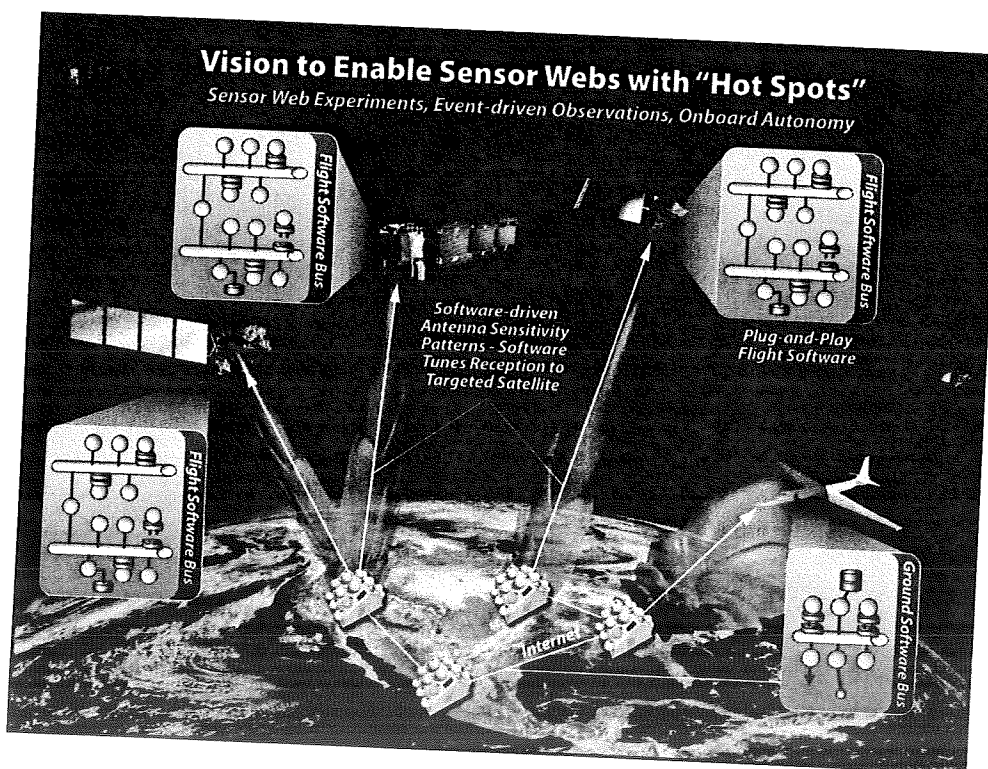
Space Technology **5**



E.g. - EO-1 Targets National Priority Wildfires

GSECI's Science Goal Monitor

- Identify NIFC-tracked Wildfire Incidents**
Large Incidents - August 21, 2003
Roberts Fire
- Correlate latest fire location information with MODIS imagery**
Roberts Fire
Aqua or Terra MODIS data
- SGM adds target to EO-1 ground & on-orbit planning & scheduling systems and tasks EO-1**
SGM
- Fire location confirmed and selected for imaging**
- EROS Data Center L1 Data**
- UMD Natural Hazards Investigation Team Active Fires Detection Map**
Roberts Fire
USFS Burned Area Emergency Response (BAER) team



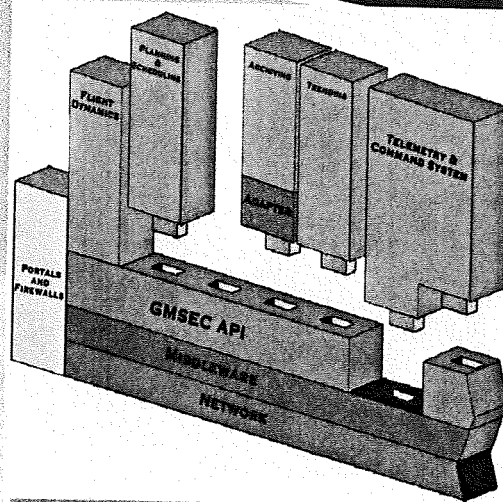


Underlying "Plug and Play" Message Bus Architecture-- Goddard Mission Services Evolution Center (GMSEC)

GMSEC architecture provides a scalable and extensible ground and flight system approach

- Standardized messages formats
- Plug-and-play components
- Publish/Subscribe protocol
- Platform transparency

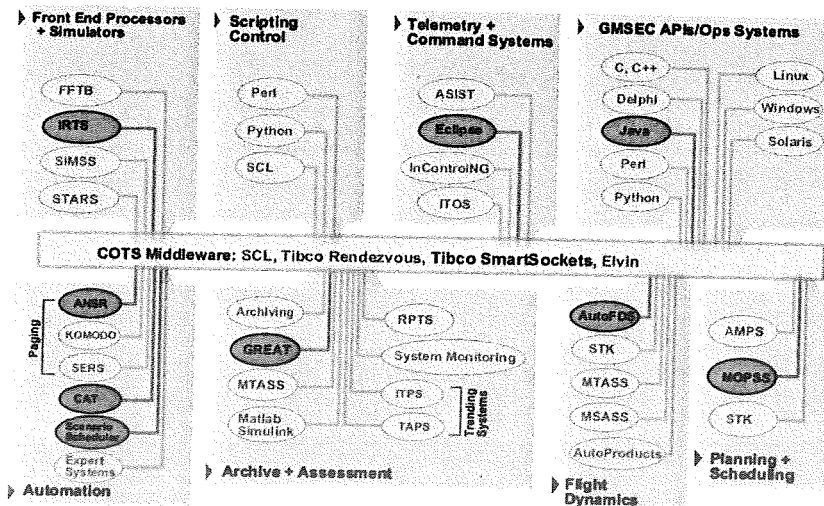
More info at: <http://gmsec.gsfc.nasa.gov>



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GMSEC Component Catalog

GMSEC approach gives users choices for the components in their system. The TRMM mission has selected key components from the GMSEC catalog.



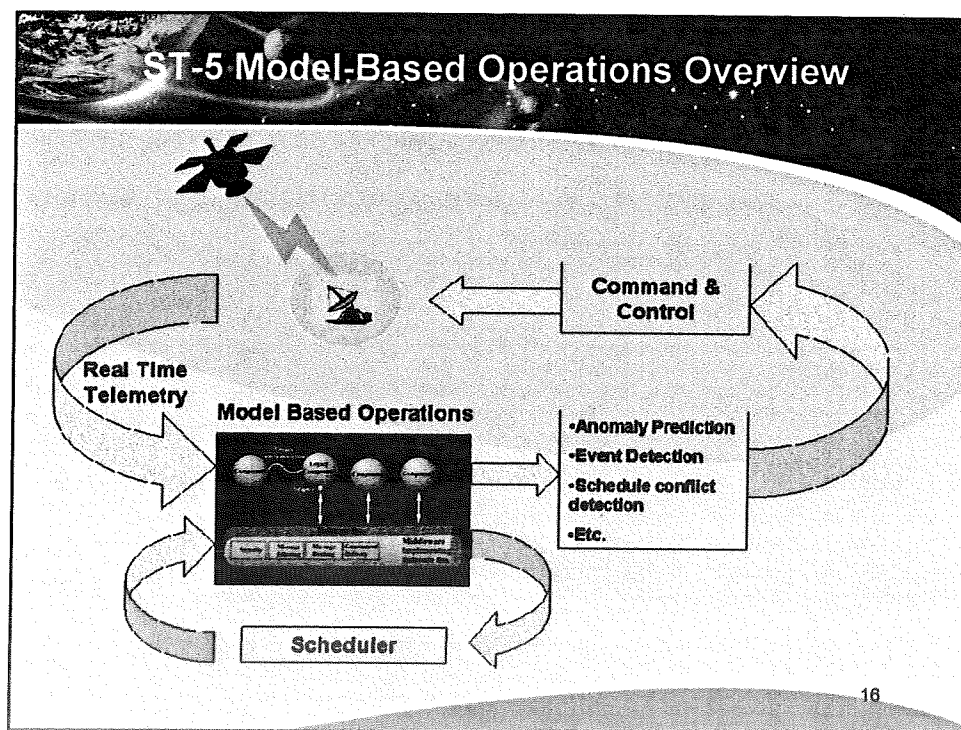
ST-5 Lights-Out Autonomy

■ ST-5 mission demonstrated parts of (1), (2), (5), (6) and (7) (from slide 3)

- Lights-out operations with model-based software
 - Predict problems before they happen and fix early
 - Models update themselves automatically
 - Modeling system is built on top of "plug and play" architecture to enable easy extensibility
- Act as stepping stone for this type of capability for future missions

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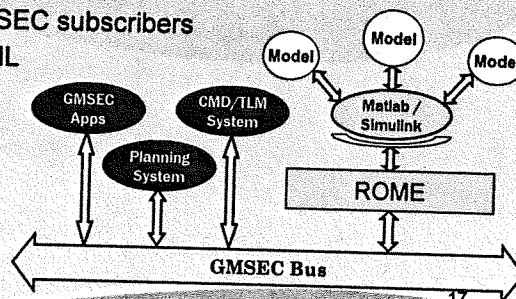
ST-5 Model-Based Operations Overview



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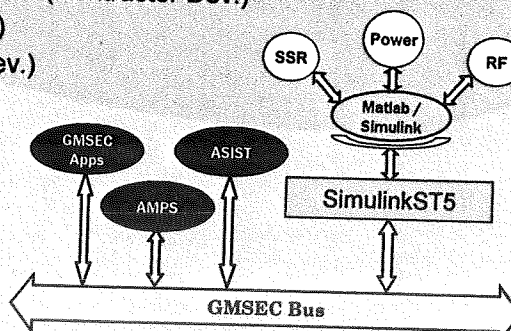
ST-5 ROME Framework

- Real-time Object Modeling Executive (ROME)
 - Supports multiple models and multiple spacecraft
 - Leverages common engineering modeling environments
 - Models from various sources are easily integrated
 - Fully supports GMSEC bus
 - Models initialized and maintained from telemetry
 - Model control via configuration file or bus directive
 - Results available to GMSEC subscribers
 - Easily configured via XML
 - Highly scalable



ST5 Specific Configuration

- ROME based implementation
- Dynamic characterization of sub-systems phenomenology
- Used by mission to manage constrained resources
- Models of Subsystems
 - Solid State Recorder (Contractor Dev.)
 - RF (Student Dev.)
 - Power (Project Dev.)



SimulinkST5 GMSEC Highlights

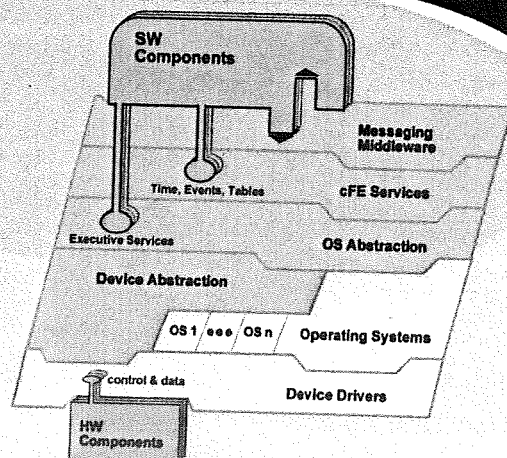
- Simulink is a visual interface to MatLab to allow users to simulate systems that can be represented with mathematical equations
- Features of Simulink as used on ST5 are as follows:
 - Standardized messaging interoperability
 - GMSEC Compliance
 - Directives
 - Advanced Mission Planning System (AMPS)
 - Advanced Spacecraft Integration and System Test (ASIST) system
 - Mnemonic Value Messages
 - ASIST
 - Integrated Test and Operations System (ITOS) capability
 - Heartbeat messages
 - Log messages
 - Product Messages
 - Predictive Model-Based Operations
 - Subsystem models to anticipate platform conditions in a constellation environment.
 - Support Short and Long Term Mission Planning
 - Interact with AMPS and ASIST for control directives, telemetry, and profile events.
 - Constellation Operations Support

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Core Flight System (CFS) and Extension for GMSEC for Flight SW

CFS provides a framework that simplifies the development and integration of applications

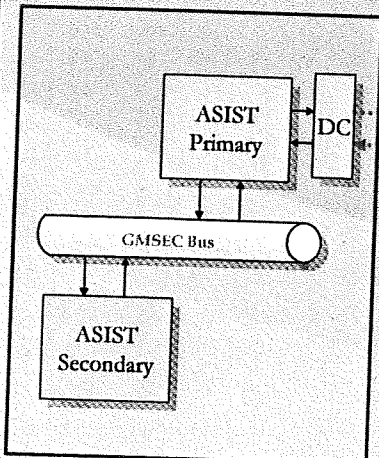
- Layered Architecture – software of a layer can be changed without affecting the software of other layers
- Components communicate over a standard message-oriented software bus, therefore eliminating the need to know the details of the lower layers of inter-networking.
- Software components can be developed and reused from mission to mission.
- Developed by Flight SW Branch at GSFC
- More info at: <http://gmsec.gsfc.nasa.gov>



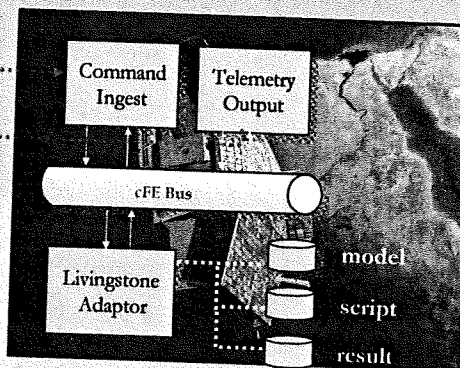
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Onboard Integrated Message Bus Demonstration (December 2005)

Ground System Testbed



cFE on CHIPS



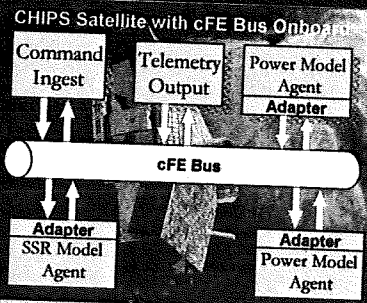
DC – Data Center

ASIST – Advanced Spacecraft Integration and System Test

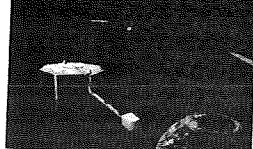
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Moving Models Onboard CHIPS Satellite Under cFS to Demonstrate Mobile Agents

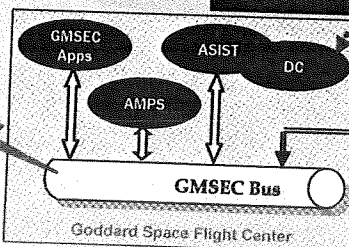
- Mobile agent –autonomous software module that can easily be moved around a network
- Models transformed into mobile agents
 - Worked with Solid State Recorder agent (model) first
- Adapter built to make compatible with both GMSEC and Core Flight Executive (cFE)
- Demonstrated capability to move software running on GMSEC onboard to run under cFE
- Demonstrates beginning step to transform missions from central control to distributed control via self-managing software



ST-5 Constellation

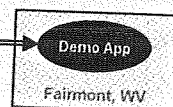


via DSN & McMurdo
Ground Stations



Goddard Space Flight Center

via Berkeley & Wallops
Ground Stations (UDP)

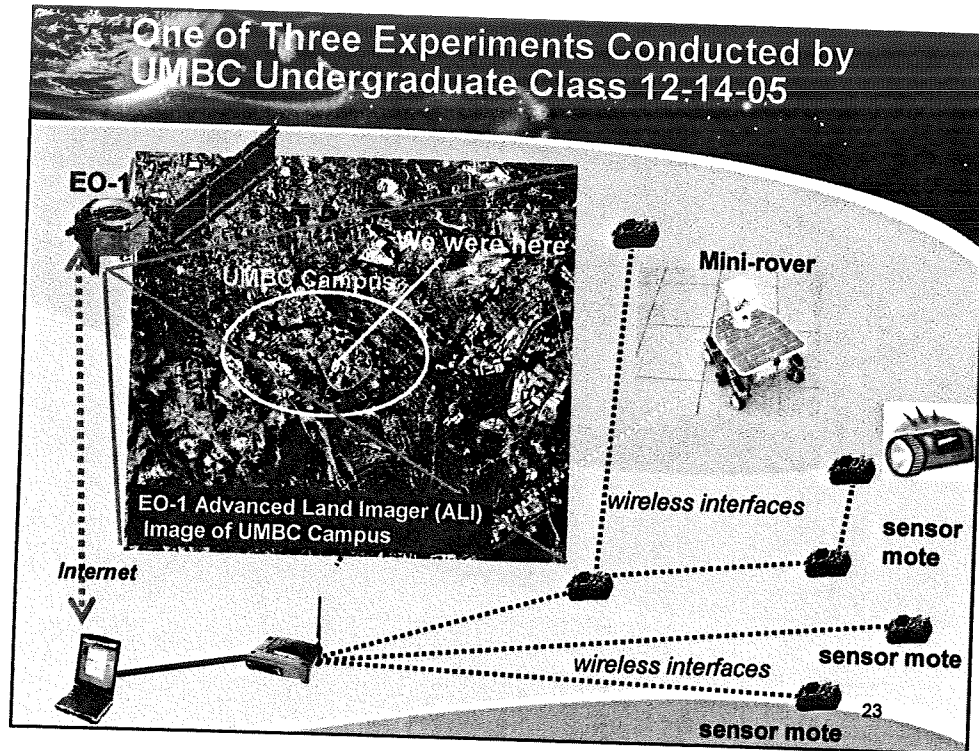


via TCP/IP

CHIPS – Cosmic Hot Interstellar Plasma Spectrometer
ST-5 – Space Technology 5

DC – Data Center
ASIST – Advanced Spacecraft Integration and System Test

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Experiment with UMBC Undergraduate Class 12-14-05

**Picture of
Experiment Day**

Sensor network class,
Dr. Younis, Vuong Ly
and Dan Mandl

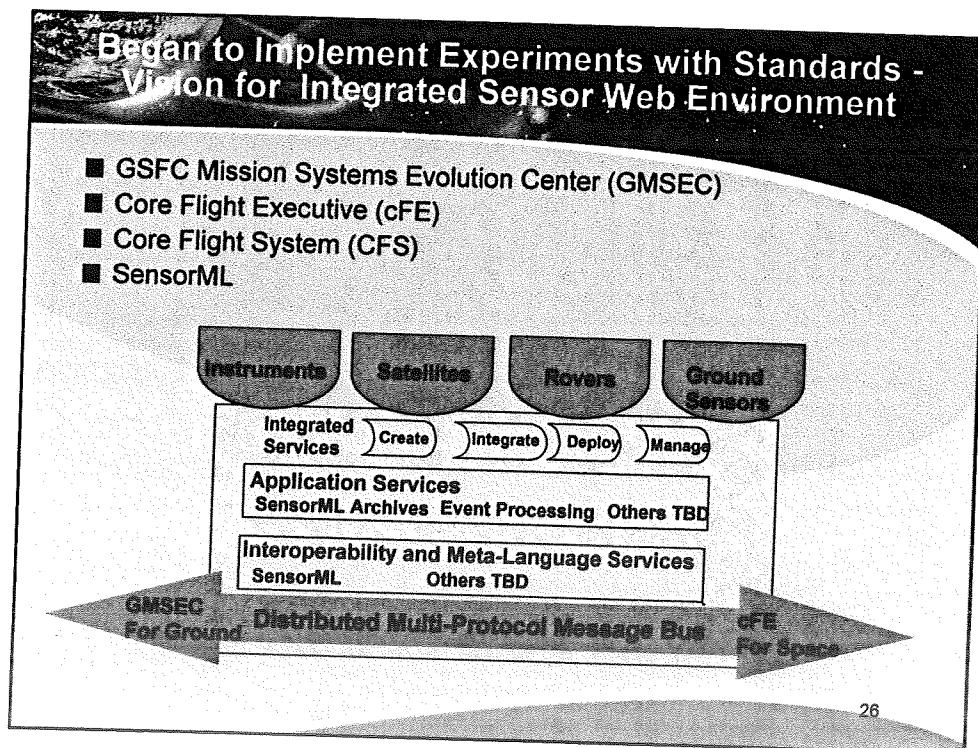
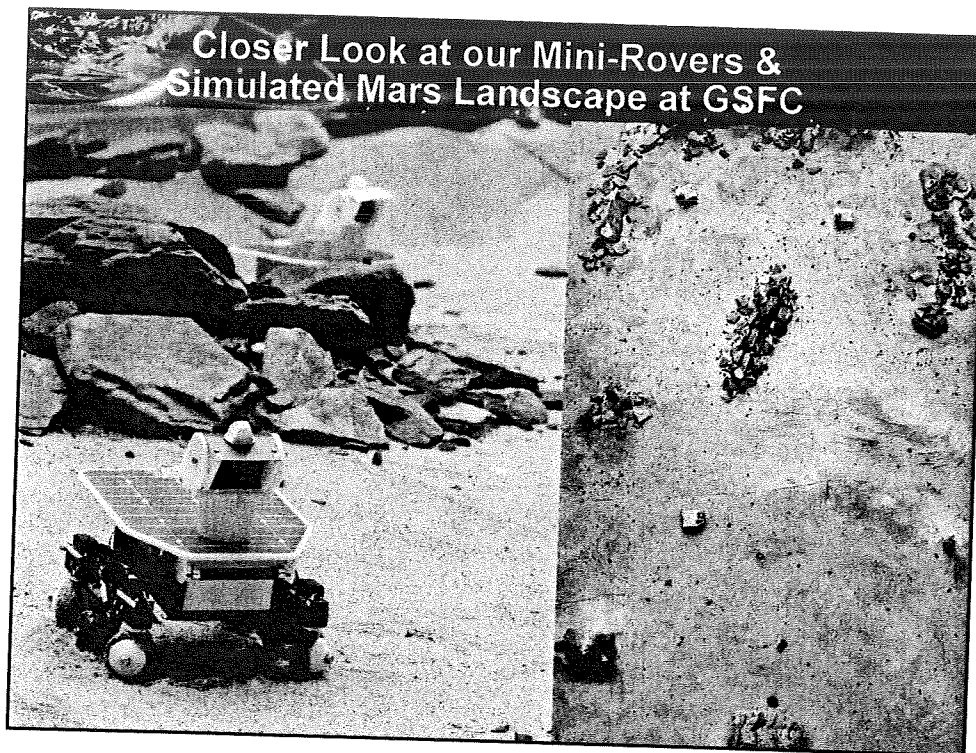
Sensor mote layout &
atrium where
experiment conducted
(inset)

Mini-rover in action

Baltimore Sun reporter

Mini-rover
autonomously
finding broken
sensor node (part of
Emergency Response
UMBC project team)

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Sensor Modeling Language (SensorML)

- Standard models and Extensible Markup Language (XML) schema
 - Describes sensor systems to provide information needed to discover and locate sensor and sensor observations
 - Process low-level observations
 - Defines interfaces
 - Lists taskable properties
- Can apply to any sensor whether in-situ or remote
- Facilitates "plug and play" and interoperability between sensors
 - Especially useful for heterogeneous sets of sensors and rapid integration of new sensors

More info at-- <http://vast.nsstc.uah.edu/SensorML/>

Good article at-- <http://www.geoplace.com/gw/2004/0406ogc.asp>

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OGC EO-1 Experiment

- A proposal was submitted and accepted by the Open Geospatial Consortium (OGC) to use EO-1 as part of a testbed effort beginning June 2006 and lasting until December 2006.
 - Testbed effort called OGC Web Services (OWS) – phase 4 has many objectives, one of which is Sensor Web Enablement (SWE) for sensors via a standard which is similar to a Service Oriented Architecture (SOA)
 - More info at:
<http://www.opengeospatial.org/initiatives/?iid=199>
 - Sponsored by many organizations including NASA, NGA, GeoConnections – Canada, National Technology Alliance, GSA, ORNL, LMCO, BAE, Ordnance Survey – UK, NATO C3, and TeleAtlas

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OGC EO-1 Experiment

- Figure on next slide depicts the portion of the demonstration in which EO-1 will participate; generic capability to discover and task EO-1 on the Internet via the following services:
 - Sensor Planning Service (SPS) – a standard Web service interface for requesting, filtering and retrieving sensor observations
 - Sensor Alert Service (SAS) – a standard interface for asynchronous notification of messages or alerts from sensors or sensor services
 - Sensor Registration Service (SRS) – a standard Web service to store sensor characteristics for later user retrieval
- Geospatial Interoperability Office at GSFC (M Bambacus, Nadine Alameh) major sponsor of OGC activities (and in particular OWS-4) and are monitoring this activity

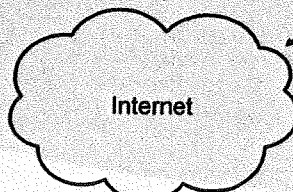
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EO-1 Participation in OGC Web Services – Phase 4 Testbed; June 2006 – December 2006

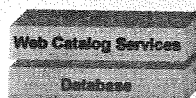
Open Geospatial Consortium (OGC) Web Services
- Phase 4 Testbed (June – December 2006)
- EO-1 portion of demonstration



- Search for satellites based on capabilities
- Register sensor in catalog to make it searchable on internet
- Command / send tasking requests via Sensor Planning Services (SPS) protocol
- Request alert service from satellite via Sensor Alert Service (SAS)



- Store capabilities
- Process user query and return the result



- Wrap EO-1 satellite in SensorML and publish its capabilities
- Enable generic command / tasking request via SPS
- Enable generic alert services via SAS

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Conclusion

- Building capabilities to enable progressive mission autonomy via the use of three satellites and a series of increasingly more capable experiments
- Focusing on validating distributed mission control and maximizing interoperability
 - Enable changes to mission post launch
 - Combine existing missions into temporary “virtual constellations” to enable new missions

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Conclusion

- Will add additional real experiments to continue to build the toolbox
 - Two recent awards for AIST ESTO call for proposal will be used
 - *An Inter-operable Sensor Architecture to Facilitate Sensor Webs in Pursuit of GEOSS – Related to OGC effort*
 - Key topic - Interoperability
 - PI: Dan Mandl - 3 year effort
 - *Using Intelligent Agents to Form a Sensor Web for Autonomous Mission Operations*
 - Key topic distributed mission control
 - PI: Ken Witt/ISR Co-I Dan Mandl/GSFC – 3 year effort

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Conclusion

- Other related awards from AIST ESTO call in March 2006 will allow possible further synergy
 - E.g. - *Increasing the Technology Readiness of SensorML for Sensor Webs*
 - » Key topic SensorML for sensor interoperability
 - » PI- Michael Botts/Univ. of Alabama – 3 year effort